BENTHIC RESUSPENSION BY INTERNAL WAVE STIMULATED GLOBAL INSTABILITY

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LONG-TERM GOAL

The long-term goal is to seek to define and describe mechanisms whereby propagating packets of long internal waves stimulate resuspension from the benthic layers under the footprint of the waves.

SCIENTIFIC OBJECTIVES

The objectives of this work is to develop quantitative predictive models for the generation and propagation of long internal wave packets on shelf regions and in semi-bounded domains; to describe the interaction of these packets with the boundary layer on variable topography; to define mechanisms whereby the boundary layer under these packets can contribute to pronounced resuspension rates; and to quantify wave conditions for which anomalously high resuspension rates are expected.

APPROACH

The approach involves an integrated mix of theoretical modeling of weakly dispersive, nonlinear internal wave propagation and its interaction with the bottom boundary layer, of direct numerical simulation of specific models of the boundary layer field under a wave packet to identify conditions for the onset of a _global_ boundary layer instability, and of examining observational evidence of packets to identify those which give evidence of strong benthic resuspension.

WORK COMPLETED

During the past year we have made progress on the objectives using all three investigative approaches described above. The work has been done in collaboration with a post-doctoral researcher Dr. Darek Bogucki. Two-space-dimensional propagation models for bi-directional internal wave propagation in the presence of variable topography and sheared currents have been developed, together with a theoretical description of the boundary layer structure in the footprint of a wave packet. At the same time, we have developed a capability for direct numerical simulation of the global instability occurring under large amplitude solitary waves. It is our firm belief that the onset of global instability in the boundary layer under a wave packet is directly responsible of the pronounced increase in resuspension under certain wave packets. We

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have also participated in field observations of propagating wave packets on a shelf; in particular, we are analyzing results form the Littoral Optical Experiment 96 with particular interest in using optical measurements to identify sites for strong resuspension and to explore the feasibility of using optical means of measuring sediment resuspension in particular environments.

RESULTS

Progress has been realized on three fronts. First, the amplitude equations for bi-directional propagation of internal waves in two-space-dimensions over variable topography, including the effect of rotation and internal Kelvin waves trapped near boundaries in semi-closed domains, have been developed. The model includes nonlinear coupling between the first two vertical modes. The next step is to develop codes to numerically integrate these model equations. This capability will give a good predictive tool for the characterizing the spatio-temporal evolution of wave packets and the associated boundary layer structure under these packets.

Second, we have developed the capability to make direct numerical simulations of the boundary layer structure under waves which impose both favorable and adverse horizontal pressure gradients on the boundary layer. The simulations allow a "exact" characterization of any fully-nonlinear global instability in the boundary layer. To date we have demonstrated the onset of global instability under an isolated solitary wave, connecting the onset of the instability directly to the amplitude of the solitary wave. It is evident that the appearance of this instability, which creates dynamics very favorable for coherent suspension of bottom sediments, occurs only for wave amplitudes exceeding some critical value. We are attempting to quantify the class of waves (amplitudes, propagation directions, background currents, etc.) for which strong resuspension is expected.

Third, we are working on the data set from Littoral Optical Experiment 96 where internal solitons were observed to cause resuspension on a shallow shelf (20 m depth). The broad, bright band signature behind the narrow packet in the upper left corner of the attached figure is directly related to optical return from suspended particulates in the water column. The obvious bands represent long internal waves. The entire image is taken via an airplane flying an S-shape pattern perpendicular to the shore line. Each strip in the figure is obtained roughly 5 minutes subsequent to its previous neighbor (appearing above and to the left in the figure). The data and photograph are courtesy of A. Weideman (Stennis NRL). Internal solitary waves are frequent features at this site and are observed to stimulate resuspension and vertical mixing. Since time increases moving from the top to the bottom in the figure, it is evident that the packet is spreading packet with, most likely, bi-directional propagation.
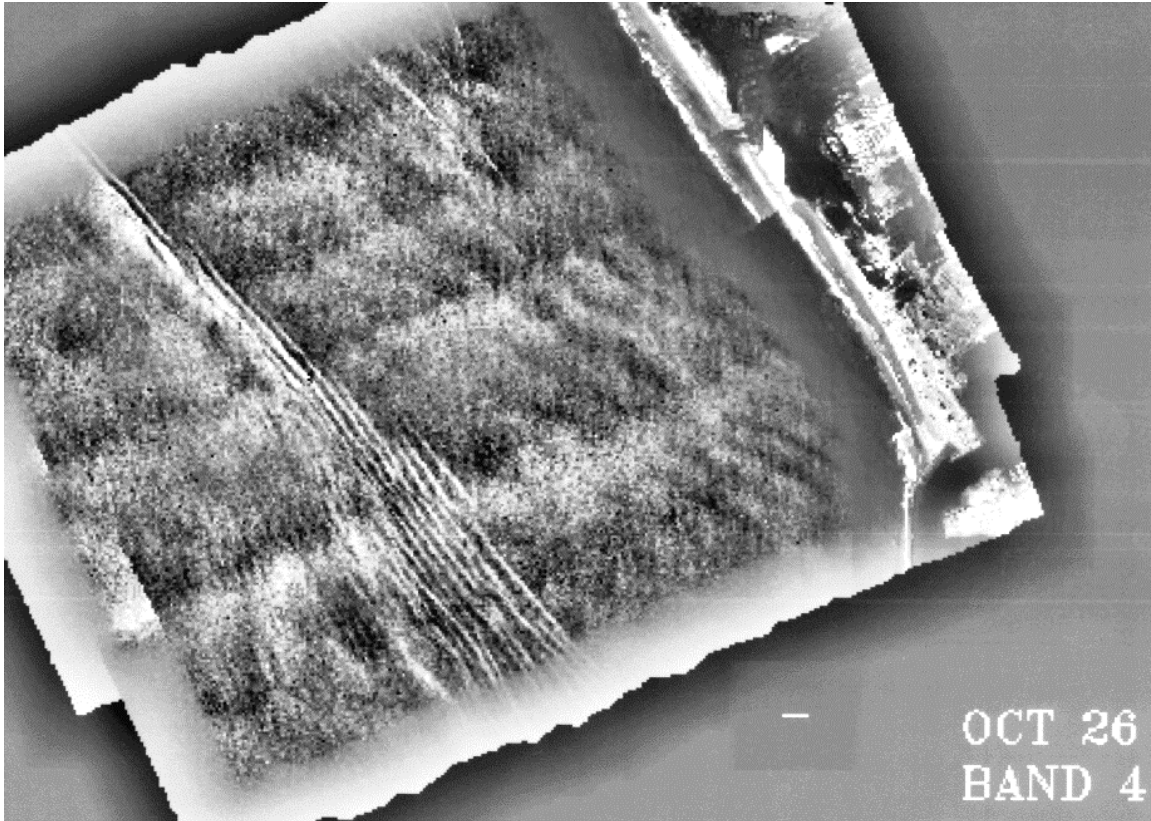
Dr. Bogucki has also participated in the Coastal Mixing & Optics experiment with Dr. J. Barth's group at Oregon State University. Packets of long internal waves, imaged by SAR, are found to be both frequent and prominent features (see Ref. 1). In this effort we will be analyzing optical (SeaSoar) data obtained by the OSU group and linking them to physical processes associated with the passing wave packets. The experimental site is instrumented with a suite of instruments (moorings, ship ADCP, stationary ADCP), affording the opportunity for testing mechanisms for wave generation, wave-boundary layer interaction, and possible resuspension detection via optical remote sensing.

IMPACT/APPLICATION

At this stage we are exploring the use of optical means for quantifying the resuspension action of long internal waves in shallow environments. We believe that this is a very attractive and potentially viable approach to obtaining quantitative estimates of resuspension occurring over a specified area on the shelf,

RELATED PROJECTS

We are collaborating with researchers both at NRL (D. Johnson and A. Weiderman) and at Oregon State University (J. Barth and associates).

REFERENCES 1. http://fermi.jhuapl.edu/cmo/radarsat index.html